ORNL's Hybrid Solar Lighting Program: Bringing sunlight inside

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ABSTRACT

This document briefly describes progress being made by the Hybrid Solar Lighting R&D Program at the Oak Ridge National Laboratory (ORNL). Hybrid solar lighting (HSL) is a new approach to lighting that integrates light from natural and electric sources. HSL systems collect and distribute the visible portion of sunlight using large-core optical fibers and combine it with electrically-generated light in existing light fixtures. The natural and electric light sources work in unison to light commercial buildings where lighting represents the single largest consumer of electricity. The program has progressed over the past two years from a conceptual design to fully-functional prototype system. Results from the prototype and accompanying cost and performance analyses show HSL is poised to outperform both PVs and conventional daylighting in commercial buildings when used to displace nonrenewable energy.

1. Program Objective

The program objective is to develop and commercialize new hybrid solar lighting systems that more than quadruple the efficiency and affordability of solar energy in commercial buildings by simultaneously separating and using different portions of the solar energy spectrum for different end-use purposes, i.e. lighting and distributed power generation. Another objective of the program is to make using sunlight directly for lighting more convenient and affordable when compared to conventional daylighting strategies. Figure 1 shows typical components in a hybrid solar lighting system.

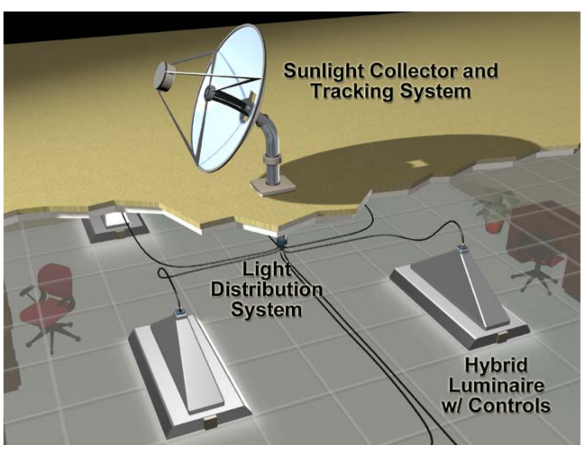

Figure 1: Hybrid Solar Lighting System Components

2. Technology Status

In September 2002, the Oak Ridge National Laboratory installed the first HSL system in a commercial building. The initial collector system (see Fig. 2) consists of a 1.1 m diameter parabolic mirror with a total collection area of 1 m^2. The secondary mirror consists of eight planar facets that focus the visible portion of sunlight into eight large core optical fibers while simultaneously transmitting the ultraviolet and infrared energy. Each collector includes a two-axis tracking system with associated controls and is mounted on a 4-inch pipe that penetrates the building roof.

Figure 2: HSL collector prototype hardware

Fig. 3. Photo of HSL laboratory being illuminated by distributed sunlight (left) and standard fluorescent lamps (right).

The amount light transmitted through each of the 8 fibers into the room(s) below is in the range of 5000 - 6000 lumens on a sunny day (see Fig. 3), which is approximately equivalent to a two state-of-the-art 32W T8 fluorescent lamps. Each of the luminaires consist of a traditional 2x4 foot light fixture containing four fluorescent lamps. The fixtures have been modified to accommodate two sunlight- diffusing rods that spatially distribute the sunlight similar to co-located electric lamps within the same fixture.

The prototype collector is only about half the size of anticipated commercial units that will collect ~2 m^2 of sunlight, penetrate the roof in one location, and distribute sunlight to 16 hybrid light fixtures. The 16 light fixtures will illuminate ~1000 ft^2 of floor space in a typical building. This equates to 8 to 10 standard size offices.

The electrical power displacement of the proof-of-concept prototype is estimated to be 522 – 2350 W per 1000 W/m^2 depending on the type of electric lights being used with the solar lighting system. This equates to a PV-equivalent system efficiency of 52 – 235%. By adding the savings in cooling load associated with reduced electric lamp use and performance improvements achieved by a system redesign now underway, the electrical power displaced in a commercial prototype is expected to be between 702 – 3160 W not including electrical power that can be generated using the otherwise wasted IR energy.

3. Comparisons with PVs and Conventional Day-lighting

There are two existing solar options for lighting commercial buildings: conventional daylighting systems that reduce electric lighting use and PV cells that generate electricity to power electric lights. Tables 1 and 2 compare the two approaches with HSL. The tables include data from an independent economic and market assessment of HSL systems developed by Antares Engineers and Economists last revised in June 2002. Daylighting comparisons are derived from cost and performance projections for needed hardware to illuminate 10 equally sized offices. Installed system costs of approximately $2.50/Wp (displacement) were derived from their analysis - suggesting such costs are achievable if existing designs are manufactured in large production quantities and time-of-day electricity prices and modest renewable energy subsidies consistent with other solar options are available.

Table 1: Comparison between HSL and PVs.

Parameter	HSL	Photovoltaics
Efficiency	70–315%	5–12%
Installed $/Wp	$2.50/Wp	$10/Wp
Payback (sunbelt)	5 years	20 years
Relative lifecycle cost	$4,700	$33,000

Table 2: Comparisons between HSL and Daylighting.

Comparative Parameter	HSL	Topside Daylighting
Relative lifecycle cost	$4700	$6600
Roof penetration area	0.3 ft2	31 ft2
Linear roof penetration	1.8 ft.	63 ft
Architectural complexity	Low	High
Reconfigurable	Yes	No
Payback period	<4 years	>10 years
Integration w/ electric lights)	Yes	No
HVAC load	Reduces	Adds to

4. Summary

This document has briefly describes progress being made by the Hybrid Solar Lighting R&D Program at the Oak Ridge National Laboratory (ORNL). Results from the prototype and accompanying cost and performance analyses show HSL is poised to outperform both PVs and conventional daylighting in commercial buildings when used to displace nonrenewable energy use

5. Acknowledgements

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